Appendix C
Herbicide Use

History of Limitations on the HMNF

Herbicides are chemicals that are utilized to suppress or kill unwanted vegetation. They are used primarily for the reduction of weeds in cropland, forests, rangelands, and many other situations, such as roadsides and right-of-ways where weed growth may be problematic. The use of herbicides as a vegetative control tool on the Huron-Manistee National Forests was halted in 1990 as part of a coordinated "Lakes States position", in which no use was be permissible under Environmental Assessments. This applied to the Chippewa, Superior, Chequamegon-Nicolet, Ottawa, Hiawatha, and Huron-Manistee National Forests. In 2003, this position was reviewed and a determination was made that herbicides could be used in the control of non-native invasive species and unwanted vegetation at administration sites. The completion of the Huron-Manistee National Forest Plan (USDA Forest Service 2006b) brings with it increased restoration efforts for a variety of endangered, threatened, and sensitive species that require savannas, barrens, and other open lands. One of these is the Karner blue butterfly.

Given the current forest condition, providing suitable habitat for this species would require the conversion of forested stands to non-forested stands. To aid in accomplishing these goals, the Huron-Manistee National Forests sought and received approval for the inclusion of herbicides as a potential tool for the prevention of increased amounts of post-harvest regeneration in areas where efforts of recovery are occurring for the Karner blue butterfly. In addition, this project would also use herbicides as a tool for limited control of aggressive, dominant ground cover, where such ground cover precludes the establishment of herbaceous nectar species critical to Karner blue butterfly recovery. This situation is limited to stands where Pensylvania sedge (and to a much less frequent degree, bracken fern) are present at high enough numbers to prevent the establishment of native nectar plants. Invasive species are defined as alien species whose introduction does, or is likely to, cause economic or environmental harm or harm to human health (Executive Order 13112 of February 3, 1999).

Registration

Herbicides cannot be distributed or sold in the United States without being registered with the Environmental Protection Agency (EPA). Before registering a new pesticide or new use for a registered pesticide, the EPA must first ensure that the pesticide (including any adjuvants, surfactants, or other ingredients comprising the product contents), when used according to label directions, can be used with a reasonable certainty of no harm to human health and without posing unreasonable risks to the environment. To make such determinations, EPA requires more than 100 different scientific studies and tests from applicants (US Environmental Protection Agency, website: *http://www.epa.gov/pesticides /regulating/registering/index.htm)*. The EPA classifies these as either general or restricted-use. The criteria for restricted-use include:

1. Danger or impairment to of public health;
2. Hazard to farm workers;
3. Hazard to domestic animals and crops; and/or
4. Damage to subsequent crops by persistent residues in the soil.

No restricted-use herbicides would be proposed for use under any of the Alternatives for this project.

Toxicity

Herbicide product labels specify how the material should be used to ensure its safety and effectiveness and are considered to be legal documents. All labels must show the following information:

- product trade name
- name of registrant (usually the manufacturer of the product)
- net weight or measure of the product
- EPA registration number
- registration number of the formulation plant or factory
- an ingredients statement containing the name and percentage of the active ingredient of the product
- percentage of the inert ingredients
- use classification (general or restricted)
- a warning or precautionary statement

Warning and precautionary statements on the product label are concerned with human toxicity and the environmental, physical, and chemical hazards associated with each material. Measurements of these hazards are typically described as LD50 or LC50. The LD50 is defined as the dose or quantity of a substance that will be lethal to 50% of the organisms in a specific test situation. It is expressed in weight of the chemical (mg) per unit of body weight (kg). Toxicants may be fed (oral LD50), applied to the skin (dermal LD50), or administered in the form of vapors (inhalation LD50). The LC50 is the concentration of a substance in air or water or continual exposure in the diet that will kill 50% of the organisms in a specific test situation. Each herbicide is assigned a toxicity category based on levels of hazard indicators, with I being the most toxic and IV being the least. The characteristics of each category are displayed in the following table.

Table C.1: Toxicity Categories and Hazard Indicators of Pesticides[1]

	Toxicity Indicators			
Hazard Indicators	**I**	**II**	**III**	**IV**
Oral LD50	Up to and including 50 mg/kg	From 50 through 500 mg/kg	From 500 through 5,000 mg/kg	Greater than 5,000 mg/kg
Inhalation LC50	Up to and including 0.2 mg/L	From 0.2 through 2 mg/L	From 2 through 20 mg/L	Greater than 20 mg/L
Dermal LD50	Up to and including 200 mg/kg	From 200 through 2,000 mg/kg	From 2,000 through 20,000 mg/kg	Greater than 20,000 mg/kg
Eye Effects	Corrosive, corneal opacity; not reversible within 7 days.	Corneal opacity; reversible within 7 days; irritation persisting for 7 days.	No corneal opacity; irritation reversible within 7 days.	No irritation
Skin Effects	Corrosive	Severe irritation at 72 hours	Moderate irritation at 72 hours	Mild or slight irritation at 72 hours

[1]*Radosevich, et al., 1997.*

Experimental data to determine toxicity levels for humans is compiled primarily through observations of small mammals (i.e. rats, rabbits, guinea pigs, etc.). Based on this data, comparative estimates are then made as to the likely quantities that would affect humans. Determining ecological toxicity requires studying the response of vegetation, birds, mammals, invertebrates, soil microorganisms, and aquatic species to a range of herbicide concentrations. The USDA compiles Risk Assessments for various compounds utilizing available experimental data. The results of this data for the herbicides being considered for this project are summarized below.

Table C.2: Mammalian (Human) Toxicity Categories for the Herbicides Being Considered for Use

	Glyphosate[1]	Triclopyr[2]	Imazapyr[3]
Oral LD50	IV (>5600 mg/kg)	III (600-1,000 mg/kg)	IV (>5,000 mg/kg)
Inhalation LC50	III (5-12 mg/L)	III (2.6 mg/L)	III (No apparent toxicity at exposure rates of 5 mg/L)
Dermal LD50	III > 5,000 mg/kg	III (2,000-5,050 mg/kg)	III (No apparent toxicity at doses of up to 2,000 mg/kg/day)
Eye Effects	Irritation varies by type	Irritation varies by type	III
Skin Effects	IV (Slight)	IV (Slight)	IV (Slight)

[1]*http://www.ipmofalaska.com/files/Glyphosate.html*
[2]*USDA Forest Service 2003b*
[3]*USDA Forest Service 2004b*

Glyphosate

Vegetation – The effects of glyphosate on plants include an inhibition or cessation of growth, cellular disruption, and, at sufficiently high levels of exposure, plant death (USDA Forest Service 2003a). The time course for these effects can be relatively slow, depending on the plant species, growth rate, climate, and application rate (USDA Forest Service 2003a). Glyphosate is absorbed primarily through the foliage, and the absorption is rapid. Glyphosate is not extensively metabolized or detoxified in plants (USDA Forest Service 2003a), and is harmless to most plants once in the soil (Tu et al. 2001). Glyphosate binds readily with soil particles, which limits its movement in the environment (Tu et al. 2001). Adsorption to soil particles prevents glyphosate from being taken-up by the roots of plants (Tu et al. 2001). Because glyphosate binds strongly to soils, it is unlikely to enter waters through surface or subsurface runoff except when the soil itself is washed away by runoff, and even then, it remains bound to soil particles and unavailable to plants (Tu et al. 2001). The half-life of glyphosate on foliage has been estimated at 10.4 to 26.6 days (Tu et al. 2001, USDA Forest Service 2003a), while residues dissipated from the fruit of exposed plants with a half-life of <13 to < 20 days (Tu et al. 2001).

Birds and Mammals – Glyphosate is of relatively low toxicity to birds and mammals (Tu et al. 2001). The LD50 of glyphosate is 5,600 mg/kg for rats and >4,640 mg/kg for bobwhite quail (USDA Forest Service 2003a). Glyphosate may cause weight loss in mammals and birds (USDA Forest Service 2003a). Inhibition of oxidative phosphorylation, which consequently reduces food conversion efficiency, has been implicated as a possible mechanism by which glyphosate causes weight loss; however, there is not adequate information about terrestrial wildlife from which to make a further assessment about the importance of this mechanism (USDA Forest Service 2003a). Glyphosate has not been shown to effect reproduction in birds (Tu et al. 2001, USDA Forest Service 2003a). However, other studies show developmental and reproductive impacts to animals given the highest dose (Tu et al. 2001).

Terrestrial Invertebrates - Data on arthropods indicate a low potential for a direct toxic effect from glyphosate (USDA Forest Service 2003a). The honey bee is the standard test organism for assessing the potential effects of pesticides on terrestrial invertebrates. The LD50 of bees is >100 ug/bee. Data on other arthropods are less detailed but also indicate a low potential for a direct toxic effect from glyphosate (USDA Forest Service 2003a). Field applications of glyphosate had no measurable direct effect - as evidenced by increased mortality or significant changes in populations - on isopods, rove beetles, butterflies, and spiders (USDA Forest Service 2003a).

Soil Microorganisms - Glyphosate is readily metabolized by soil bacteria (USDA Forest Service 2003a). There is very little information suggesting that glyphosate will be harmful to soil microorganisms under field conditions and a substantial body of information indicating that glyphosate is likely to enhance or have no effect on soil microorganisms (USDA Forest Service 2003a). Laboratory and field studies have reported direct toxic effects on microflora and microfauna including protozoa, algae, bacteria, cyanobacteria, and fungi (Tu et al. 2001, USDA Forest Service 2003a). However, some researchers found that microorganisms recovered rapidly from treatment with glyphosate, suggesting the herbicide posed no long-term threat (Tu et al. 2001). Glyphosate has also been reported to have stimulatory effects on microorganisms. Several field studies involving microbial activity in soil after glyphosate exposures note an increase rather than decrease in soil microorganisms or microbial activity (USDA Forest Service 2003a).

Aquatic Species - Glyphosate is of moderate toxicity to aquatic species (Tu et al. 2001). The 96-hour LC50 of technical grade glyphosate for bluegill sunfish and rainbow trout are 120 mg/L and 86 mg/L (USDA Forest Service 2003a). The 48-hour LC50 of technical grade glyphosate to Daphnia is 780 mg/L, substantially higher than the 96-hour LC50 values in freshwater fish (USDA Forest Service 2003a). The toxicity of different glyphosate formulations can vary considerably in large part due to what surfactant is used (Tu et al. 2001a, USDA Forest Service 2003a). For example, the 96-hour LC50 of glyphosate alone is 962 mg/L for Daphnia, but the LC50 of Roundup® drops to 25.5 mg/L because the surfactant in Roundup® formulations, MONO818®, is more toxic to aquatic organisms (Tu et al. 2001). Despite higher toxicity levels, researchers applying Roundup® with MONO818® or Rodeo® with the surfactant X-77 Spreader® have found that treatments using these formulations do not significantly affect the survival of aquatic invertebrates (e.g., Daphnia) and algae (e.g., diatoms) (Tu et al. 2001). It appears that under most conditions, rapid dissipation from aquatic environments prevents build-up of herbicide concentrations that would be lethal to most aquatic species (Tu et al. 2001).

Deformities in free-living amphibians have increased concern for the effects of xenobiotics like herbicides on populations of amphibians. Researchers found no statistically significant increase in abnormalities in frog embryos exposed to glyphosate formulations, including those with surfactants, at levels that were not lethal (USDA Forest Service 2003a). Studies have determined that the 48-hour LC50 values for juvenile frogs are 51.8 mg a.e./L for Roundup 360 and 83.6 mg/L for technical grade glyphosate, and the 48-hour LC50 values for tadpoles are 11.6 mg a.e./L for Roundup 360 and 121 mg/L for technical grade glyphosate (USDA Forest Service 2003a). Although tadpoles appear to be somewhat more sensitive than juveniles, the reported LC50 values are in the range of those seen in fish (USDA Forest Service 2003a). Researchers reported no effect on populations of six species of amphibians (based on capture rates) among clearcut sites with and without glyphosate applications (USDA Forest Service 2003a).

Table C.3: Characteristics of Glyphosate

Relative To:	Characteristics		
Risks to Human Health	Low toxicity to mammals. Has not shown evidence of carcinogenicity in humans. Negative in tests for mutagenicity. Low risk of general health effects for multiple exposures of ground based applications. Can cause skin and eye irritation.		
Behavior of Glyphosate in Water Included Toxicity Data on Fish and Aquatic Animals	**Solubility**	**Half-life**	**Characteristics**
	Rapidly dissipated through adsorption to suspended and bottom sediments.	12 days to 10 weeks.	Technical grade is moderately toxic to fish. A formulation is registered for aquatic use that is practically non-toxic to fish, aquatic invertebrates, and amphibians. Does not bioaccumulate in fish.
Mobility in the Air	Does not readily volatilize.		
Mobility and Persistence in the Soil	**Mechanisms of Degradation**	**Half-life in the Soil**	**Mobility**
	Degradation is primarily due to soil microbes.	Average of 47 days.	Glyphosate has an extremely high ability to bind to soil particles, preventing it from being mobile in the environment.
Toxicity Data on Birds, Mammals, and Invertebrates	**Toxicity to Birds and Mammals**	**Toxicity to Other Organisms**	**Bioaccumulation**
	Low toxicity to birds and mammals.	No long-term threat to terrestrial invertebrates or microbial populations.	In mammals, the vast majority is excreted unchanged and does not bioaccumulate.
Toxicology on Amphibians	Results of the Frog Embryo Teratogenic bioassay –Xenopus (FETAX) demonstrated that with proper use of selected varieties of glyphosate, there were not any effects on the normal development of larval frogs.		

(1) Tu et al. 2001 (2) USDA Forest Service 2003a

Triclopyr

Vegetation – Triclopyr mimics indole auxin plant growth hormones and causes uncontrolled growth in plants (USDA Forest Service 2003b). At sufficiently high levels of exposure, the abnormal growth is so severe that vital functions cannot be maintained and the plant dies (USDA Forest Service 2003b). There are two basic formulations of triclopyr – a triethyamine salt and a butoxyethyl ester. In soils, both formulations are rapidly degraded to triclopyr acid (Tu et al. 2001). Offsite movement through surface or subsurface runoff is a possibility with triclopyr acid, as it is relatively persistent and has only moderate rates of adsorption to soil particles (Tu et al. 2001). Both the salt and ester formulations are hydrolyzed to the acid form after entering plant tissue (Tu et al. 2001), which tends to remain in plants until they die. Because triclopyr is persistent in foliage and twigs, concentrations of triclopyr in the soil can rise when contaminated leaves fall from defoliating crowns (Tu et al. 2001). In addition, residues in fruit have been shown to persist up to one month; thus, there is a potential for long-term exposure of triclopyr to animal species that eat wild fruit (Tu et al. 2001). In non-target plants, triclopyr soil residues can cause damage via root uptake (Tu et al. 2001).

Birds and Mammals – Triclopyr is regarded as only slightly toxic to birds and mammals (Tu et al. 2001). The oral LD50 is 630-729 mg/kg for rats, 2,935 mg/kg for bobwhite quail, and 1,698 mg/kg for mallard ducks (USDA Forest Service 2003b). The kidney appears to be the primary target tissue for triclopyr in mammals (USDA Forest Service 2003b). Reproductive or teratogenic effects occur only at doses that cause maternal toxicity (USDA Forest Service 2003b). Researchers suggested that triclopyr would not be present in animal forage in doses large enough to cause either acute or chronic effects to wildlife, and concluded that the tendency for triclopyr to dissipate quickly in the environment would preclude any problems with bioaccumulation in the food chain (Tu et. al. 2001). Sub-lethal doses of triclopyr ester have been found to cause weight loss and behavior alterations in birds (Tu et al. 2001). Garlon 3A can cause severe eye damage to wildlife due to the high pH of its water-soluble amine salt base (Tu et al. 2001).

Terrestrial Invertebrates – Studies of the toxicity of triclopyr or triclopyr formulations on terrestrial vertebrates are only known for the honey bee (USDA Forest Service 2003b). Triclopyr is of low toxicity to honey bees, with a LD50 value of >100 ug/bee (USDA Forest Service 2003b).

Soil Microorganisms - Little information is available on the toxicity of triclopyr to terrestrial microorganisms (USDA Forest Service 2003b). In lab experiments, triclopyr reduced the growth of four types of ectomycorrhizal fungi associated with conifer roots at concentrations of ≥1,000 parts per million (ppm), with total growth inhibition occurring at ≥ 5,000 ppm (Tu et al. 20 01, USDA Forest Service 2003b). However, typical usage in forest plantations results in triclopyr residues of only four to 18 ppm on the forest floor (Tu et al. 2001, USDA Forest Service 2003b).

Aquatic Species – Triclopyr acid and the salt formulations are slightly toxic to fish and aquatic invertebrates (Tu et al. 2001). The 96-hour LC50 of the acid and salt formulations are 117 mg/L and 552 mg/L for rainbow trout and 148 mg/L and 891 mg/L for bluegill sunfish, and the 48-hour LC50 of these formulations for Daphnia is 133 mg/L and 775 mg/L (USDA Forest Service 2003b). However, the ester formulation can be extremely toxic to fish and aquatic invertebrates (Tu et al. 2001, USDA Forest Service 2003b). The 96-hour LC50 for the ester formulation is 0.74 mg/L for rainbow trout, 0.87 mg/L for bluegill sunfish, and 1.7 for Daphnia (USDA Forest Service 2003b). Although the ester formulation degrades rapidly to less toxic forms, lethal effects have been seen in fish exposed to low level residues for more than six hours or exposed to high concentrations for a short duration (Tu et al. 2001). This finding is of concern given that researchers found organisms subjected to direct overspray were exposed to a high level of herbicide for short periods of time, while organisms downstream were exposed to low levels for longer periods (Tu et al. 2001). However, most researchers have concluded that triclopyr would not be found in concentrations adequate to kill aquatic organisms if applied properly in accordance with the manufacturer label (Tu et al. 2001). As in fish, the ester formulation was found to be more toxic to amphibians than the acid and salt formulations (USDA Forest Service 2003b). The 96-hour LC50 values for embryos were 5,407 mg a.e./L for the acid formulation and 9.3 mg/L for the ester formulation (USDA Forest Service 2003b). Researchers found no statistically significant increase in abnormalities in frog embryos exposed to acid, salt, or ester formulations of triclopyr at levels that were not lethal.

Table C.4: Characteristics of Triclopyr

Relative To:	Characteristics		
Risks to Human Health	Slightly toxic to mammals. Evidence of carcinogenicity in humans is marginal. Can cause irritation to skin and eyes. Garlon 3A can cause severe eye damage to both humans and wildlife.		
Behavior of Triclopyr in Water Included Toxicity Data on Fish and Aquatic Animals	**Solubility**	**Half-life**	**Characteristics**
	Salt formulation is water-soluble; ester formulation is not.	Salt formulation can degrade in sunlight with a half-life of several hours. The ester formulation takes longer to degrade.	Ester formulation is extremely toxic to fish and aquatic invertebrates. Acid and salt formulation is lightly toxic to fish and aquatic invertebrates. The hydrophobic nature of the ester formulation allows it to be readily absorbed through fish tissues where it is converted to triclopyr acid which can be accumulated to a toxic level. However, most authors have concluded that if applied properly, triclopyr would not be found in concentrations adequate to harm aquatic organisms.
Mobility in the Air	Ester formulations can be volatile, and care should be taken during application. Salt formulation is much less volatile than the ester formulation.		
Mobility and Persistence in the Soil	**Mechanisms of Degradation**	**Half-life in the Soil**	**Mobility**
	Rapidly degraded to triclopyr acid by photolysis, microbes in the soil, and hydrolysis.	30 days.	Ester formulation binds readily with the soil, giving it low mobility. The salt formulation binds only weakly in soil, giving it higher mobility (%). However, both formulations are rapidly degraded to triclopyr acid, which has an intermediate adsorption capacity, thus limiting mobility.
Toxicity Data on Birds, Mammals, and Invertebrates	**Toxicity to Birds and Mammals**	**Toxicity to Other Organisms**	**Bioaccumulation**
	Slightly toxic to birds and mammals.	No long-term threat to terrestrial invertebrates or microbial populations.	Tendency for triclopyr to dissipate quickly in the environment precludes any problems with bioaccumulation in the food chain.
Toxicology on Amphibians	Results of the Frog Embryo Teratogenic bioassay – With proper use, triclopyr formulations do not have a significant effect on the normal development of larval frogs.		

(1) Tu et al. 2001 (2) USDA Forest Service 2003b

Imazapyr

Vegetation – Imazapyr can control a wide variety of plants, but is practically non-toxic to conifers (USDA Forest Service 2004b). It inhibits acetolactate snythase and thereby prevents the synthesis of branched-chain amino acids that is required for growth (Tu et al. 2001, USDA Forest Service 2004b). The rate of plant death is usually slow (several weeks) and is likely related to the amount of stored amino acids available to the plant (Tu et al. 2001). Imazapyr is not metabolized extensively in plants but is transported rapidly from treated leaves to root systems (USDA Forest Service 2004b). Treated plants may exude imazapyr from their roots into the surrounding soil, posing a risk to neighboring non-target plants (Tu et al. 2001, USDA Forest Service 2004b). The adsorption of imazapyr to soil particles is generally weak, but can vary depending on soil properties including pH and moisture (Tu et al. 2001). Under most field conditions, imazapyr is relatively persistent and can be highly available in the environment (i.e., water and soil), increasing the potential risk to desirable non-target plant species (Tu et al. 2001).

Birds and Mammals – Imazapyr is of relatively low toxicity to birds and mammals (Tu et al. 2001, USDA Forest Service 2004b). The LD50 of imazapyr is >5,000 mg/kg for rats and >2,150 mg/kg for bobwhite quail and mallard ducks (USDA Forest Service 2004b). Studies with rats indicate that imazapyr was excreted rapidly in the urine and feces with no residues accumulating in the liver, kidney, muscle, fat, or blood (Tu et al. 2001, USDA Forest Service 2004b). Imazapyr has not been found to cause mutations or birth defects in animals, and shows no evidence of carcinogenicity (Tu et al. 2001, USDA Forest Service 2004b).

Terrestrial Invertebrates – Studies of the toxicity of imazapyr on terrestrial vertebrates are only known for the honey bee (USDA Forest Service 2004b). Imazapyr is of low toxicity to honey bees, with a LD50 of >100 ug/bee (USDA Forest Service 2004b).

Soil Microorganisms – Relatively little information is available on the toxicity of imazapyr to terrestrial microorganisms (USDA Forest Service 2004b). The effects of imazapyr on bacteria appear to be highly species specific. In lab experiments, imazapyr inhibited the growth of two strains of plant-associated bacteria (*Bacillus*), whereas three other species of *Bacillus*, as well as several additional soil bacteria, were not affected (USDA Forest Service 2004b). The manufacturers report that Arsenal® is non-mutagenic to bacteria (Tu et al. 2001). In addition, imazapyr has been shown to inhibit rates of cellulose decomposition and carboxymethyl cellulase activity in peat soil with 59% organic carbon (USDA Forest Service 2004b).

Aquatic Species – Imazapyr is of low toxicity to fish and aquatic invertebrates (Tu et al. 2001). The LC50s for rainbow trout, bluegill sunfish, channel catfish, and Daphnia are all >100 mg/L (USDA Forest Service 2004b). In addition, a 21-day chronic study on Daphnia noted no effects on reproduction or growth at concentrations of up to 97.1 mg/L (USDA Forest Service 2004b). Imazapyr concentrations of up to 1600 mg/L have not been found to affect the osmoregulatory capacity of Chinook salmon smolts (Tu et al. 2001). Other research suggests that imazapyr is moderately toxic to other fish species (USDA Forest Service 2004b). The 96-hour LC50 values of imazapyr for silver barb and Nile Tilapia are 2.71 mg/L and 4.36 mg/L (USDA Forest Service 2004b). A *"nearly significant effect on hatching"* was observed in a study of the toxicity of imazapyr on the early life-stages of rainbow trout (USDA Forest Service 2004b). However, the concentrations tested in these studies are substantially above concentrations that may be expected in the normal use of imazapyr (USDA Forest Service 2004b). No data is available concerning the toxicity of imazapyr to amphibian species (USDA Forest Service 2004b). No bioconcentration and no effect in the growth of oyster shell were found in studies of the toxicity of imazapyr on mollusks (USDA Forest Service 2004b).

Table C.5: Characteristics of Imazapyr

Relative To:	**Characteristics**		
Risks to Human Health	Low toxicity to mammals. Evidence of non-carcinogenicity. Can cause skin and eye irritation, with some formulations causing severe, irreversible eye damage.		
Behavior of Imazapyr in Water Included Toxicity Data on Fish and Aquatic Animals	**Solubility**	**Half-life**	**Characteristics**
	May undergo photodegradation.	2 days.	Has low toxicity to fish and invertebrates, and algae and submersed vegetation are not affected. Imazapyr is registered for use in aquatic areas.
Mobility in the Air	Does not volatize readily when applied in the field.		
Mobility and Persistence in the Soil	**Mechanisms of Degradation**	**Half-life in the Soil**	**Mobility**
	Degraded primarily by microbial metabolism.	1 to 5 months.	Below pH 5, the adsorptive capacity of imazapyr increases and limits its movement in soil. Above pH 5, greater concentrations of imazapyr become negatively charged, fail to bind tightly with soils, and remain available for plant uptake and/or microbial breakdown.
Toxicity Data on Birds, Mammals, and Invertebrates	**Toxicity to Birds and Mammals**	**Toxicity to Other Organisms**	**Bioaccumulation**
	Relatively low toxicity to birds and mammals.	Low toxicity to terrestrial invertebrates and microorganisms.	Imazapyr is not expected to bioaccumulate in the food chain.
Toxicology on Amphibians	No data is available concerning the toxicity of imazapyr to amphibian species.		

(1) Tu et al. 2001 (2) USDA Forest Service 2004b

Factors of Effectiveness

The effectiveness of herbicide applications is influenced by selectivity. In plants this is often conditional and based on such factors as:

- plant tolerance to the herbicide
- herbicide rate (dosage)
- time of application
- stage of weed and/or crop development
- weather patterns
- variation in microenvironment or microtopography
- variation in resource level
- soil type and pH

Plant characteristics may also influence their response to herbicides. These factors include: genetic inheritance, age, growth rate, morphology, and physiological and biological processes.

The most effective use of herbicides occurs when these are taken into consideration, in conjunction with the herbicide selectivity (Radosovich et al. 1997). Herbicides are used in accordance with the recommendations provided in the product label. The rate of application is typically listed as the amount of chemical per unit land area. Examples of the rate of application are pounds per acre (lbs/ac) or kilograms per hectare (kg/ha). Furthermore, the rate of application may be considered in terms of the amount of active ingredient applied or the amount of formulated product. The rate of application for the target species in this project would not exceed the maximum allowable quantity listed in the product label. There are a variety of methods for herbicide application. The method that is selected for each application is based on the type and characteristics of the chemical, the characteristics and abundance of the target species, the type of equipment available, economics, and site-specific resource concerns.

Additives

Adjuvants are materials that are mixed spray solutions or suspensions to improve the performance, handling, or application of herbicides. They are chemicals and may be a part of the herbicide solution when it is purchased or they may be added later. Terms used to describe adjuvants include activators, additives, dispersing agents, emulsifiers, spreader, stickers, surfactants, thickeners, and wetting agents. Each is unique and promotes different characteristics in the solution. The proposed herbicide application for this project would occur post-emergence (after the target species has emerged in the spring). As a result, it would be anticipated that surfactants would be used to enhance the herbicide effectiveness. According to Radosovich (1997), it is believed that surfactants intensify the activity of herbicides by:

- creating uniform spreading or wetting on leaf surfaces
- increasing spray droplet retention
- improving spray droplet and leaf surface contact
- solubilizing non-polar plant substances
- causing enzymatic denaturation or membrane dysfunction

Methods of Application

There are many types of sprayers that are available for use in the application of herbicides. For the spot-treatments proposed under this project, it is likely that application would occur via hand-held spray bottles or backpack sprayers. These are commonly used to apply small quantities of herbicides in hard to access areas. In areas identified for seeding, broadcast spraying of herbicides may occur to prepare the seedbed. While these areas will not exceed 10% of stand acreage, they may be larger than what can be reasonably treated with either hand-held spray bottles or backpack sprayers. In these locations, mounted boom sprayers may be utilized. For this project, the method of application would be determined on a site-by-site basis and would be selected to provide the maximum benefits with the least amount of residual effects. Following, is a brief description of the equipment mentioned (MSU Extension 2002):

Hand-held Spray Bottles – Typically hold up to one quart of spray mixture. There is a spray filter within the bottle (attached to the outlet tube) to prevent impurities from clogging the spray mechanisms. Trigger may be manually or battery operated. Used for spot-treatments in isolated areas or in areas where the type of vegetation requires targeted applications of low volume quantities.

Backpack Sprayers – Compressed air sprayer with a harness that allows it to be carried on the applicators back. Pressure within the tank is obtained through the pumping of a hand-lever. An adjustable spray hose is operated by the other hand. A mechanical agitator plate may be attached to the pump plunger. Some sprayers may generate pressures of up to 100psi or more. The volume capacity of these sprayers is usually 5 gallons. These sprayers are common for the spot-treatment of herbicides in both agriculture and forestry.

Boom Sprayers – These are low pressure sprayers that are often equipped with sprayer booms ranging from 10 to 60 feet in length and containing several nozzles. Typically, the height of the boom is easily adjustable to meet the needs of the job. Many nozzle arrangements are possible, and special-purpose booms are available.

Timing of Application

All of the herbicides being considered for use under this project are considered to be post-emergent. This means that the chemicals would be applied to the foliage or the cut stump after the target plants have emerged. The applied herbicides then translocate from the point of application throughout the plant. Herbicides with this mode of action are referred to as systemic and promote the suppression of root, rhizome, or shoot growth at a considerable distance from the point of application (Radosovich et al. 1997). The process of contact, penetration and movement of herbicides through plants is called absorption. For the sake of this project, the following three steps of adsorption would be pertinent:

1. retention of spray droplets on the leaf/stump surface;
2. the penetration of the herbicide into plant cells; and
3. movement into the cytoplasm of the plant cell.

The timing of the herbicide application for this project would be partially dependent on the life cycle of the Karner blue butterfly. These considerations would be most applicable in stands showing a surveyed presence of this species and the pertinent mitigation measures would be adhered to. In the stands without a historical or surveyed presence of this species, the timing would be determined based on the likelihood of effectiveness. This varies by target species and recommendations are given in the product label. In addition to the time of year, consideration would also be given to the micro-climate (i.e. soil type, topography, etc.) of the treatment areas and the current and anticipated weather. This would be done to ensure that an adequate spray window was utilized in the right location to maximize effectiveness.

This page left intentionally blank.